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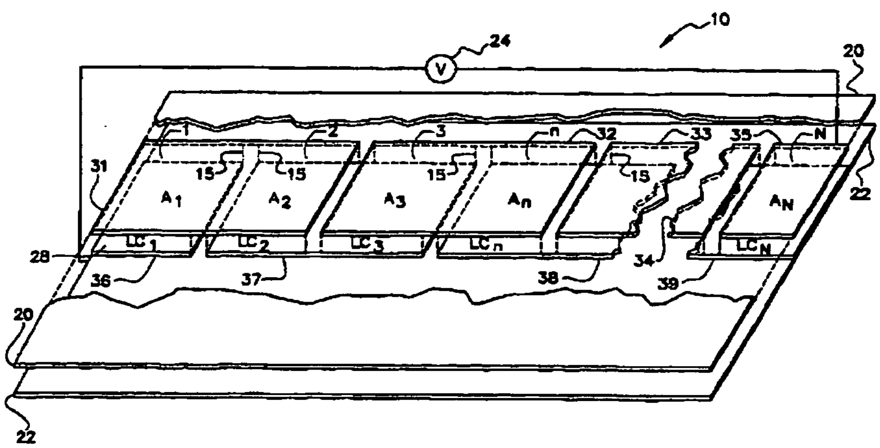

(57) Abstract

Self-referenced half-tone, gray scale liquid crystal display having pixels that are subdivided into subpixels ($A_1...A_N$). Each of the subpixels have transparent electrodes (31-39) with a liquid crystal material sandwiched between the electrodes. The electrodes of each subpixel and the liquid crystal dielectric constitute the subpixel capacitor which also functions as a control capacitor for the control capacitor. Each of the subpixel electrodes on one end of the dielectric overlap another subpixel but the electrode on the other end overlaps still another subpixel. The structure is such that the subpixel capacitors are electrically connected in series. The subpixels have electrodes of various areas and thus the subpixel capacitors of the pixel have different values. Application of a voltage across all of the series-connected subpixels of the pixel may result in the activation of none, one, or more subpixels of the pixel, in accordance with the magnitude of the voltage; the subpixels having the lower capacitances turning on first as the applied voltage is increased from zero, since the greater voltage drop occurs across the smaller-valued capacitors. Thus, each pixel of the display has a gray scale capability that is a function of the applied voltage.

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SELF-REFERENCED HALF-TONE LIQUID CRYSTAL DISPLAY

BACKGROUND OF THE INVENTION

The present invention pertains to liquid crystal displays (LCD's) and particularly to LCD's having half-tone pixels.

The related art discloses LCD's having half-tone pixels. Such half-tone pixels are composed of subpixels having separate control capacitors. The subpixels, wherein each subpixel has a series control capacitor, are connected in parallel. Each control capacitor is introduced into the structure of the liquid crystal panel resulting in a somewhat complex structure that can be difficult to fabricate.

U.S. Patent 4,840,460, entitled "Apparatus and Method for Providing a Gray Scale Capability in a Liquid Crystal Display Unit," by Bernot et al., and issued on June 20, 1989, is hereby incorporated by reference. Also, U.S. Patent 5,204,659, entitled "Apparatus and Method for Providing a Gray Scale in Liquid Crystal Flat Panel Displays," by K. Sarma, and issued on April 20, 1993, is hereby incorporated by reference.

SUMMARY OF THE INVENTION

The present invention incorporates a half-tone pixel that needs not to introduce separate control capacitors. The subpixels of the half-tone pixels by themselves constitute the control capacitors. The subpixels are arranged in a serpentine manner and electrically connected in series wherein the plate of one subpixel extends over and couples across to the plate of the next subpixel. By placing the subpixels physically and electrically in series, and by setting the specific area, thickness and dielectric coefficient of each subpixel, each subpixel can have a particular subpixel transmissivity and thus a turn-on sequence as a function of voltage. One advantage or feature of this invention is the need for fewer material layers and reduction in complexity of a half-tone display.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of the capacitances associated with the subpixels of a pixel.

Figure 2 reveals a structure incorporating the self-referenced half-tone subpixel.

Figures 3a-h show several subpixel configurations.

Figures 4a-b are of subpixel film schematics for several combinations.

Figures 5a-f reveal combined series and parallel subpixel configurations in corresponding electrical and structural schematics.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Capacitors 1, 2, 3, n and N of figure 1 represent capacitances C_{LC1}, C_{LC2}, C_{LC3}, C_{LCn} ... C_{LCN}, respectively, associated with subpixels 1, 2, 3, n through subpixel N, within a pixel. Pixel 10 is a glass sandwich which may have a well-known low cost standard twisted nematic type liquid crystal material 28 between glass sheets 20 and 22. Other liquid crystal materials or structures may be used, e.g. ferro-electric, polymer dispersed, smectic, supertwist, electrically controlled birefringence, etc. Glass sheet 20 can be coated with transparent but electrically conductive indium tin oxide (ITO) film layers 31, 32, 33, 34 and 35. Glass sheet 22 is coated with transparent and electrically conductive ITO film layers 36, 37, 38 and 39. Areas A_1, A_2, A_3, A_n and A_N of the respective subpixels 1, 2, 3, n and N, are determined by the overlap of films 31 and 36, 31 and 37, 32 and 37, 32 and 38, and 35 and 39. The overlapping ITO films 31-39 form the electrodes or plates for each of the subpixels which are effective capacitors having liquid crystal material 28 as a dielectric. The areas A_1, A_2, A_3, A_n and A_N are different thereby resulting in different capacitances for each of the subpixels 1, 2, 3, n and N. Coincident with the subpixel areas are the respective electric fields indicated by, for instance, broken lines 15. Because of the various capacitances, the subpixels are each activated at different levels of applied voltage from source 24. The amount of voltage 24 applied determines the number of subpixels that are activated thereby resulting in a specific gray scale of the pixel comprising the subpixels, and thus providing gray scale capability for a liquid crystal display.

Typically, the number of subpixels practical for this configuration is from two to four. One, however, may design a configuration having five to twenty, or more, subpixels per pixel. Figures 3a, 3b and 3c show three-, six- and nine-subpixel configurations 11, 12 and 13, respectively, as instances of the invention. Figure 3a reveals a "stacked" subpixel configuration wherein the film electrodes sequentially overlap in an ascending manner. Figures 3d-e show various attachments of electrodes 43 and 44 to configurations 41 and 42, respectively. Figures 3f-g reveal subpixel configurations 45 and 46 that correspond to configurations 41 and 42, respectively, but have pixels with a wider aspect ratio. Configuration 47 of figure 3h is a structural

design for a three subpixel pixel. Figure 4a shows a parallel-series subpixel electrode layout having main electrode connections 50 and 51. Figures 5a and 5b are corresponding electrical 52 and structural 53 schematics for a pixel having a parallel subpixel electrode connection. Figures 5c and 5d reveal a four subpixel series-parallel approach in electrical schematic 54 and structural layout 55. In figures 5e and 5f is a three subpixel series-parallel approach in electrical configuration 56 and corresponding structure 57. The point is that combinations of serial and parallel approaches can be used to achieve specific design goals. The subpixels composing a pixel may be of any number, and form the pixel in any shape, figure, such as a circle or triangle, or design. Further, the subpixels may be of various colors.

For a saturation voltage of 90 percent and a cutoff voltage of 10 percent, the voltages for sequentially activating the subpixels of a two subpixel pixel are about 9 and 12 volts, respectively. For a three subpixel pixel the activating voltages are about 9, 13 and 20 volts respectively. About 50 volts is needed to activate all the subpixels of a four-subpixel pixel. Thus, an increase of the number of subpixels in a pixel requires a notable increase of voltage. The amount of required drive voltages for subpixel activation may be reduced by increasing the amount of optical overlap of one subpixel with respect to another, for instance, such as the saturation voltage of 80 percent and a cutoff voltage of 20 percent increases the overlap and reduces the amount of drive voltage to activate all of the subpixels of a pixel.

The equations that follow below provide an electrical analysis of subpixel operation. Subpixels 1, 2, 3, n ... N are arranged in series and are designated by their impedances $1/sC_1$, $1/sC_2$, $1/sC_3$, $1/sC_n$, ... $1/sC_N$ respectively, wherein the subscript n designates the number of the subpixel of concern and N indicates the total number of subpixels. The areas A_1, A_2, A_3, A_n, ... A_N of subpixels 1, 2, 3, n and N, are designed and arranged such that one subpixel is at a different voltage than its neighbor. In view of Ohm's law, the pixel having the smallest capacitance has the highest impedance and thus obtains the highest share of a voltage applied to the pixel's capacitive voltage divider network. The below equations determine the area sizes of subpixels 1, 2, 3, n and N, required to sequentially activate the subpixels. As the applied voltage is increased, subpixels 1 through N activate in succession. Voltage 24 is applied across series capacitive network 26. The equations 1-8, as set forth below, are for designing

the activation of subpixels 1 through N at the 10 percent and 90 percent optical transmission points. Specific areas for respective subpixels 1, 2, 3 and n are calculated with these equations. Equations 9-21 are for determining subpixel impedances and saturation voltages. The impedance Z_{n-1} of each subpixel 1 through n is shown to be related to neighboring subpixels in accordance with $Z_{n-1} = KZ_n$, where $K = ((V_{90}/V_{10}) \bullet \varepsilon)$, V_{10} and ε is the ratio if the parallel dielectric coefficient $\varepsilon_\parallel$ to the perpendicular dielectric coefficient $\varepsilon_\perp$ of liquid crystal material 28. That is,

$$\varepsilon = \varepsilon_\parallel/\varepsilon_\perp.$$

Z_1, Z_2, Z_3 and Z_n, where $Z_n = 1/j\varpi C_n$, correspond to subpixel capacitors 1, 2, 3 and n of figure 1, and are the impedances of subpixels 1, 2, 3 and n of figure 2, respectively, wherein each subpixel is in series with n-1 subpixels for a dielectric constant of the liquid crystal material when the subpixel is inactivated, i.e., the voltage across the subpixel is less than or equal to V_{10}. $\varepsilon_\parallel$ is the dielectric constant of liquid crystal when the "off" voltage across the liquid crystal is $\leq V_{10}$. $\varepsilon_\perp$ is the case where the oblong molecules are perpendicular to the otherwise applied electric field between the subpixel electrodes. $\varepsilon_\parallel$ is the dielectric constant of the liquid crystal material when the oblong molecules are parallel to the applied electric field between the subpixel electrodes, that is, having a "saturated" voltage V_{SAT} across the pixel equal to or greater than V_{90}. The liquid crystal dielectric is an anisotropic material that seeks a minimum energy state. Basic plate capacitor equations include $C = k_e\varepsilon_o(A/D)$ and $E = 1/2(q^2/C)$; where k_e is the relative permittivity of the uniform isotropic dielectric between the capacitor electrodes, ε_o is the permittivity of free space, A is the effective area of the electrodes, D is the distance between the electrodes, and q is the amount of charge on the capacitor of concern.

The following expressions are design equations for determining the parameters for the subpixel configurations disclosed above.

$$V_{90} = \frac{\varepsilon^{-1} Z_N}{\varepsilon^{-1} \sum_{n=1}^{N} Z_n} \cdot V_{SAT_N} \qquad (1)$$

$$V_{SAT_N}=\frac{\varepsilon^{-1}\sum_{n=1}^{N}Z_n}{\varepsilon^{-1}Z_N}\cdot V_{90} \qquad (2)$$

$$V_{10}=\frac{Z_N}{\varepsilon^{-1}\sum_{n=1}^{N-1}Z_n+Z_N}\cdot V_{ON_N} \qquad (3)$$

$$V_{90}=\frac{\varepsilon^{-1}Z_{N-1}}{\varepsilon^{-1}\sum_{n=1}^{N-1}Z_n+Z_N}\cdot V_{SAT_{N-1}} \qquad (4)$$

$$V_{ON_N}=\frac{\varepsilon^{-1}\sum_{n=1}^{N-1}Z_n+Z_N}{Z_N}\cdot V_{10} \qquad (5)$$

$$V_{SAT_{N-1}}=\frac{\varepsilon^{-1}\sum_{n=1}^{N-1}Z_n+Z_N}{\varepsilon^{-1}Z_{N-1}}\cdot V_{90} \qquad (6)$$

Let

$$V_{ON_N}=V_{SAT_{N-1}} \qquad (7)$$

$$\frac{\varepsilon^{-1}\sum_{n=1}^{N-1}Z_n+Z_N}{Z_N}\cdot V_{10}=\frac{\varepsilon^{-1}\sum_{n=1}^{N-1}Z_n+Z_N}{\varepsilon^{-1}Z_{N-1}}\cdot V_{90} \qquad (8)$$

$$\frac{V_{10}}{Z_N}=\frac{V_{90}}{\varepsilon^{-1}Z_{N-1}} \qquad (9)$$

$$\frac{V_{10}}{V_{90}}\varepsilon^{-1} Z_{N-1} = Z_N \qquad (10)$$

or

$$Z_{N-1} = \frac{V_{90}}{V_{10}}\varepsilon Z_N \qquad (11)$$

Let

$$K = \frac{V_{90}}{V_{10}}\varepsilon \qquad (12)$$

$$Z_{n-1} = KZ_N \qquad (13)$$

By induction,

$$V_{SAT_n} = V_{90} \cdot \frac{\varepsilon^{-1}\sum_{n=1}^{n} Z_n + \sum_{n=n+1}^{N} Z_n}{\varepsilon^{-1} Z_n} \qquad (14)$$

but

$$\begin{aligned}\sum_{n=n+1}^{N} Z_n &= Z_{n+1} + Z_{n+2} + \ldots Z_{N-1} + Z_N \\ &= K^{N-n-1} Z_N + K^{N-n} Z_N + \ldots KZ_N + Z_N \\ &= Z_N \cdot (1 + K + \ldots K^{N-n+1}) \\ &= Z_N \cdot \frac{(1-K^{N-n})}{(1-K)}\end{aligned} \qquad (15)$$

$$\sum_{n=1}^{n} Z_n = Z_1 + Z_2 + \ldots Z_{n-1} + Z_n \qquad (16)$$

but

$$Z_n = KZ_{n+1} + K^{N-n} Z_N \qquad (17)$$

so

$$\begin{aligned}\sum_{n=1}^{n} Z_n &= K^{N-n+n-1} Z_N + \ldots K^{N-n+1} Z_N + K^{N-n} Z_N \\ &= K^{N-1} Z_N + \ldots K^{N-n+1} Z_N + K^{N-n} Z_N \\ &= Z_N K^{N-n}(1 + K \ldots K^{n-1}) \\ &= Z_N K^{N-n} \frac{(1-K^n)}{(1-K)}\end{aligned} \qquad (18)$$

$$V_{SAT_n} = V_{90} \frac{[\varepsilon^{-1} Z_N \, K^{N-n} \dfrac{(1-K^n)}{(1-K)} + Z_N \dfrac{(1-K^{N-n})}{(1-K)}]}{\varepsilon^{-1} Z_n} \qquad (19)$$

$$\begin{aligned}Z_n &= KZ_{n+1} \\ &= K^{N-n} Z_N\end{aligned} \qquad (20)$$

$$V_{SAT_n} = V_{90} \cdot \frac{(\varepsilon^{-1} K^{N-n}(1-K^n) + (1-K^{N-n}))}{(1-K)\varepsilon^{-1} K^{N-n}} \qquad (21)$$

THE CLAIMS

1. A self-referenced half-tone liquid crystal display, having at least one pixel utilizing a parallel/series subpixel electrode configuration, comprising:

a first conductive film having a first area;

a second conductive film, proximate and parallel to said first film, having a second area aligned with the first area, wherein the second area has the same size as that of the first area, and the second area of said second conductive film is at a first distance from the first area of said first film; and

a third conductive film, proximate and parallel to said second conductive film, having a fourth area aligned with a third area of said second film, wherein the fourth area has the same size as that of the third area, and the fourth area of said third conductive film is at a second distance from the third area of said second film.

2. The pixel of claim 1, further comprising a fourth conductive film, proximate and parallel to said third film, having a sixth area aligned with a fifth area of said third film, wherein the sixth area has the same size as that of the fifth area, and the sixth area of said fourth conductive film is at a third distance from the fifth area of said third conductive film.

3. The pixel of claim 2, further comprising a fifth conductive film, proximate and parallel to said fourth film, having an eighth area aligned with a seventh area of said fourth film, wherein the eighth area has the same size as that of the seventh area, and the eighth area of said fifth conductive film is at a fourth distance from the seventh area of said fourth conductive film.

4. The pixel of claim 3, further comprising a sixth conductive film, proximate and parallel to said fifth film, having a tenth area aligned with a ninth area of said fifth film, wherein the tenth area has the same size as that of the ninth area, and the tenth area of said sixth conductive film is at a fifth distance from the ninth area of said fifth conductive film.

5. The pixel of claim 4, further comprising a seventh conductive film, proximate and parallel to said sixth film, having a twelfth area aligned with an eleventh area of said sixth film, wherein the twelfth area has the same size as that of the eleventh area, and the twelfth area of said seventh conductive film is at a sixth distance from the eleventh area of said sixth conductive film.

6. The pixel of claim 5, further comprising:

an eighth conductive film, proximate and parallel to said seventh film, having a fourteenth area aligned with a thirteenth area of said seventh film, wherein the fourteenth area has the same size as that of the thirteenth area, and the fourteenth area of said eighth conductive film is at a seventh distance from the thirteenth area of said seventh conductive film;

a ninth conductive film, proximate and parallel to said eighth film, having a sixteenth area aligned with a fifteenth area of said eighth film, wherein the sixteenth area has the same size as that of the fifteenth area, and the sixteenth area of said ninth conductive film is at a eighth distance from the fifteenth area of said eighth conductive film; and

a tenth conductive film, proximate and parallel to said ninth film, having an eighteenth area aligned with a seventeenth area of said ninth film, wherein the eighteenth area has the same size as that of the seventeenth area, and the eighteenth area of said tenth conductive film is at a ninth distance from the seventeenth area of said ninth conductive film.

7. The pixel of claim 1, wherein:

said first and third films are adhered to a first plate;

said second film is adhered to a second plate;

a liquid crystal material is situated between first and second plates;

a first voltage electrode is connected to said first conductive film;

a second voltage electrode is connected to said third conductive film;

aligned first and second areas form a first subpixel of said pixel; and

aligned third and fourth areas form a second subpixel of said pixel.

8. The pixel of claim 2, wherein:
said first and third films are adhered to a first plate;
said second and fourth films are adhered to a second plate;
a liquid crystal material is situated between first and second plates;
a first voltage electrode is connected to said first conductive film;
a second voltage electrode is connected to said fourth conductive film;
aligned first and second areas form a first subpixel of said pixel;
aligned third and fourth areas form a second subpixel of said pixel; and
aligned fifth and sixth areas form a third subpixel of said pixel.

9. The pixel of claim 3, wherein:
said first, third and fifth films are adhered to a first plate;
said second and fourth films are adhered to a second plate;
a liquid crystal material is situated between first and second plates;
a first voltage electrode is connected to said first conductive film;
a second voltage electrode is connected to said fifth conductive film;
aligned first and second areas form a first subpixel of said pixel;
aligned third and fourth areas form a second subpixel of said pixel;
aligned fifth and sixth areas form a third subpixel of said pixel; and
aligned seventh and eighth areas form a fourth subpixel of said pixel.

10. The pixel of claim 5, wherein:
said first, third, fifth and seventh films are adhered to a first plate;
said second, fourth and sixth films are adhered to a second plate;
a liquid crystal material is situated between first and second plates;
a first voltage electrode is connected to said first conductive film;
a second voltage electrode is connected to said seventh conductive film;
aligned first and second areas form a first subpixel of said pixel;
aligned third and fourth areas form a second subpixel of said pixel;
aligned fifth and sixth areas form a third subpixel of said pixel;
aligned seventh and eighth areas form a fourth subpixel of said pixel;
aligned ninth and tenth areas form a fifth subpixel of said pixel; and

aligned eleventh and twelfth areas form a sixth subpixel of said pixel.

11. The pixel of claim 6, wherein:

said first, third, fifth, seventh and ninth films are adhered to a first plate;

said second, fourth, sixth, eighth and tenth films are adhered to a second plate;

a liquid crystal material is situated between first and second plates;

a first voltage electrode is connected to said first conductive film;

a second voltage electrode is connected to said tenth conductive film;

aligned first and second areas form a first subpixel of said pixel;

aligned third and fourth areas form a second subpixel of said pixel;

aligned fifth and sixth areas form a third subpixel of said pixel;

aligned seventh and eighth areas form a fourth subpixel of said pixel;

aligned ninth and tenth areas form a fifth subpixel of said pixel;

aligned eleventh and twelfth areas form a sixth subpixel of said pixel;

aligned thirteenth and fourteenth areas form a seventh subpixel of said pixel;

aligned fifteenth and sixteenth areas form an eighth subpixel of said pixel; and

aligned seventeenth and eighteenth areas form a ninth subpixel of said pixel.

12. The pixel of claim 1 wherein at least one said pixel forms a half-tone liquid crystal display.

13. A self-referenced half-tone liquid crystal display comprising at least one pixel, wherein each pixel comprises:

a first conductive film having a first area; and

an Nth conductive film having an (2N-2)th area proximate to a (2N-3)th area of an (N-1)th conductive film, wherein N ranges sequentially from a positive integer greater than one to a positive integer indicating a total number of conductive films.

14. A self-referenced half-tone liquid crystal display comprising at least one pixel, wherein each pixel comprises:

a first conductive film having a first area; and

an (N-1)th conductive film having an (N- 1)th area proximate to and overlapping the (N- 1)th area of an (N-2)th conductive film and having an Nth area; and

wherein:

the (N-1)th areas overlap and result in an (N-1)th subpixel and an (N-1)th subpixel capacitor;

an Nth conductive film having an Nth area proximate to and overlapping the Nth area of an (N-1)th conductive film; and

wherein:

the Nth areas overlap and result in an Nth subpixel and an Nth subpixel capacitor; and

wherein:

N is an appropriate integer from a complete set of positive integers ranging from three through a greatest integer; and

the greatest integer represents a total number of conductive films in each said pixel.

15. A self-referenced half-tone liquid crystal display comprising:

a first non-conductive plate;

a second non-conductive plate parallel and proximate to said first plate; and

at least one pixel wherein each pixel comprises N conductive films on said first and second plates, wherein each of said films on said second plate overlaps two of said films on said first plate, and, in turn, each of said films on said first plate overlaps two of a group of said films on said second plate, such that said films overlap each other, each area of overlap results in a subpixel of said pixel and in a capacitance of the respective subpixel, the overlapping films begin a first film, sequentially end with an Nth film and result in subpixels and subpixel capacitances electrically connected in series.

16. The display of claim 15 further comprising a liquid crystal material sandwiched between said first and second plates.

17. The display of claim 16 wherein:

a first voltage terminal is connected to a first film;

a second voltage terminal is connected to the Nth film; and

each subpixel is activated at a particular voltage which is dependent, at least in part, on an amount of overlap constituting the respective subpixel.

18. A gray-scale liquid crystal display having at least one pixel element, said pixel element comprising:

a first surface having a plurality of conducting elements;

a second surface having a plurality of conducting elements, said second surface being approximately parallel to and at a distance from said first surface; and

wherein:

most conducting elements on said first surface overlap at the distance from two conducting elements on said second surface, and vice versa, overlapping elements being sequential and serial;

each overlapping of two conducting elements on said first and second surfaces, forms a subpixel and a subpixel capacitance, such that resultant subpixels and subpixel capacitances of said pixel are electrically connected in series; and

a liquid crystal material situated between said first and second surfaces.

19. The display of claim 18, wherein subpixel capacitances have various values, such that an applied voltage on two conducting elements at opposite ends of a series of overlapping conducting elements of said first and second surfaces results in a portion of the applied voltage across each subpixel capacitance, and that none, one, or more subpixels are activated in accordance with the amount of the applied voltage, resulting in said pixel element having gray-scale capability as a function of voltage magnitude.

20. A method of implementing a gray-scale for a pixel in a liquid crystal display, comprising:

dividing an area of the pixel into a plurality of subpixel areas on first and second surfaces, the first and second surfaces being approximately parallel to each other and at a distance from each other;

forming a first plurality of conducting elements on the first surface of subpixel areas in that almost every conducting element covers a pair of adjacent subpixel areas;

forming a second plurality of conducting elements on the second surface of the subpixel areas in that almost every conducting element covers a pair of adjacent pixel areas, resulting in an overlapping of conductive elements on the first surface with the conductive elements of the second surface in that a conducting element on the first surface and a conducting element on the second surface in each subpixel area result in a subpixel and a corresponding subpixel capacitor, and all of the resulting subpixel capacitors of the pixel being electrically connected in series; and

placing a liquid crystal material between the first and second surfaces.

21. The method of claim 20 further comprising applying a voltage across the series of subpixel capacitors, such that none, one, or more subpixels are activated according to a magnitude of the voltage thereby resulting in the pixel having a gray-scale capability as a function of voltage.

22. A self-referenced half-tone liquid crystal display, having at least one pixel utilizing a parallel/series subpixel electrode configuration, comprising:

a first conductive film having a first area;

a second conductive film, proximate and parallel to said first film, having a second area aligned with the first area, wherein the second area has the same size as that of the first area, and the second area of said second conductive film is at a first distance from the first area of said first film;

a third conductive film, proximate and parallel to said second conductive film, having a fourth area aligned with a third area of said second film, wherein the fourth area has the same size as that of the third area, and the fourth area of said third conductive film is at a second distance from the third area of said second film;

a fourth conductive film having a fifth area;

a fifth conductive film, proximate and parallel to said fourth film, having a sixth area aligned with the fifth area, wherein the sixth area has the same size as that of the fifth area, and the sixth area of said fifth conductive film is at a third distance from the fifth area of said fourth film;

a sixth conductive film, proximate and parallel to said fifth conductive film, having a eighth area aligned with a seventh area of said fifth film, wherein the eighth area has the same size as that of the seventh area, and the eighth area of said sixth conductive film is at a fourth distance from the seventh area of said fifth film;

a first voltage terminal connected to said first and fourth conductive films; and

a second voltage terminal connected to said third and sixth conductive films.

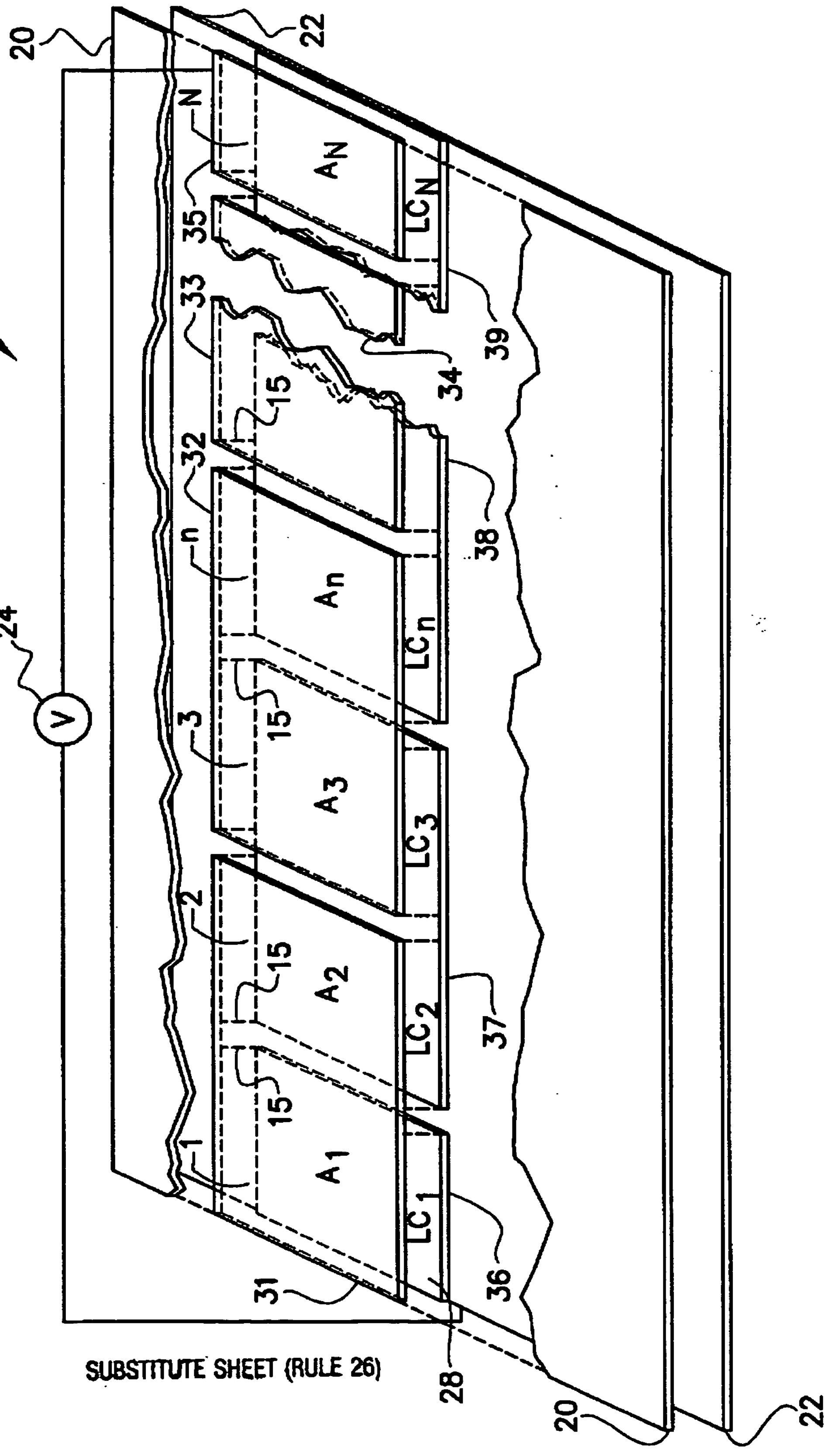
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Fig.2

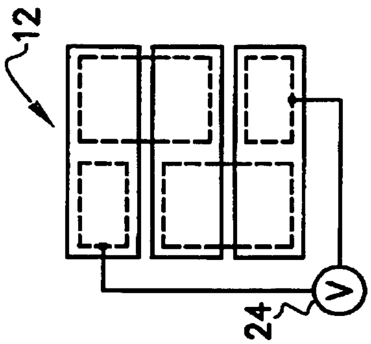


Fig. 3B

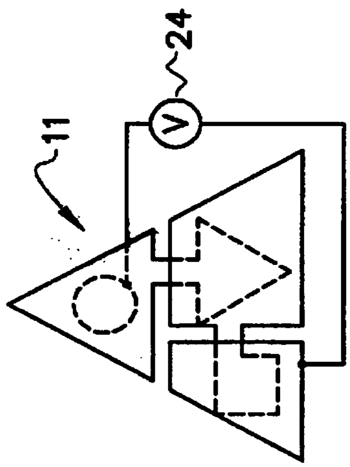


Fig. 3A

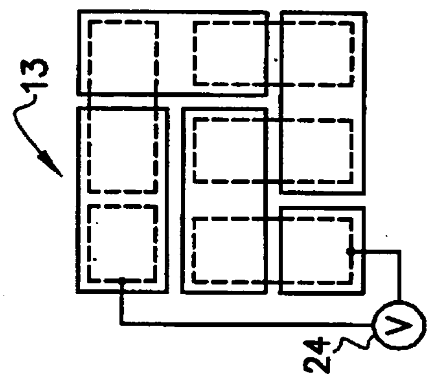


Fig. 3C

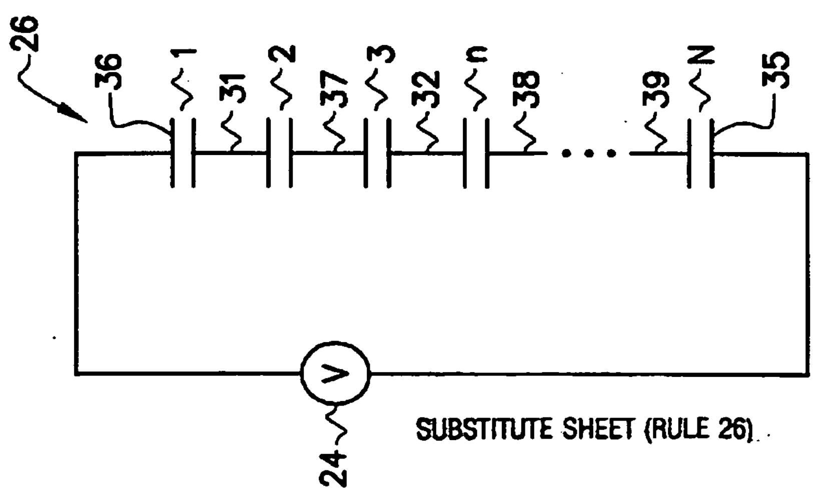


Fig. 1

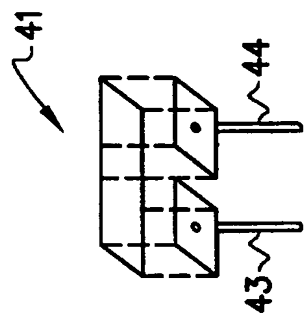


Fig.3D

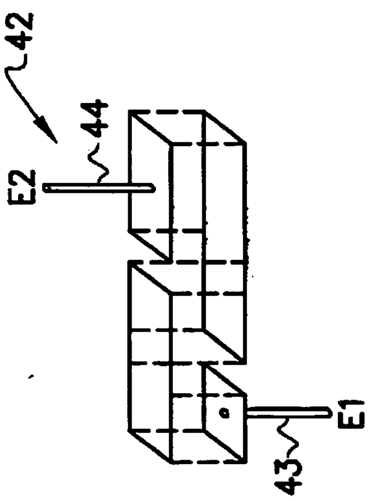


Fig.3E

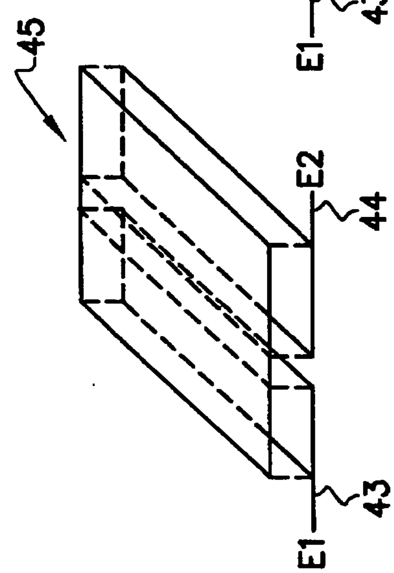


Fig.3F

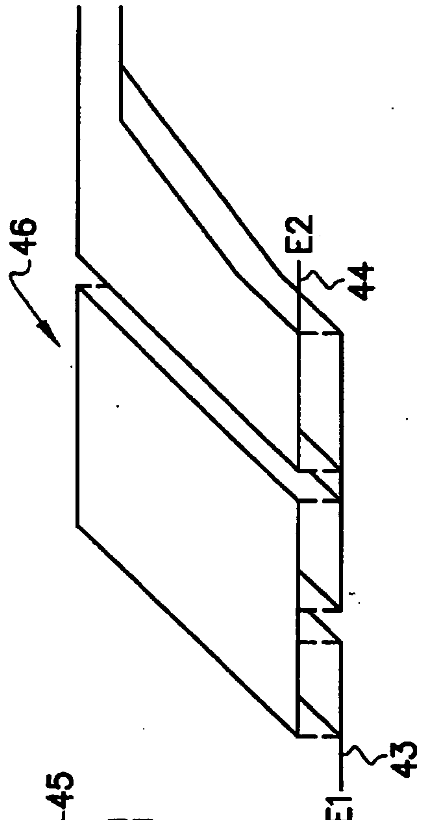


Fig.3G

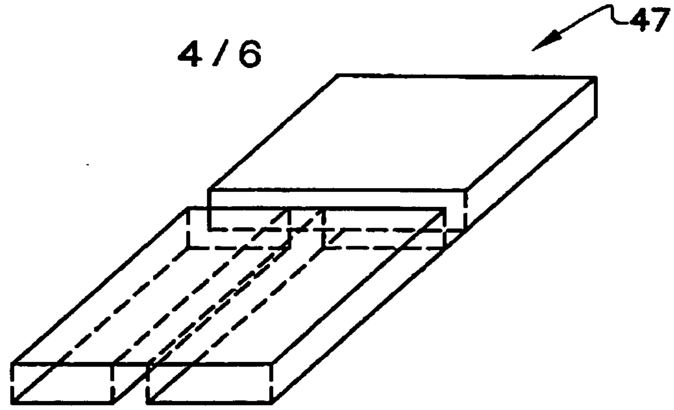


Fig. 3H

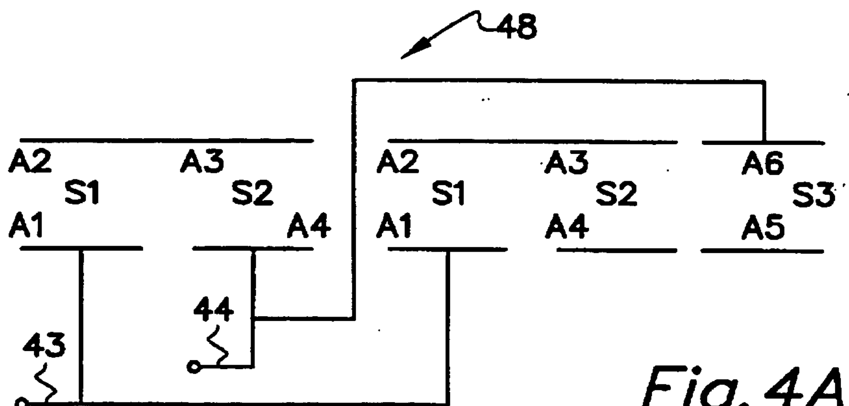


Fig. 4A

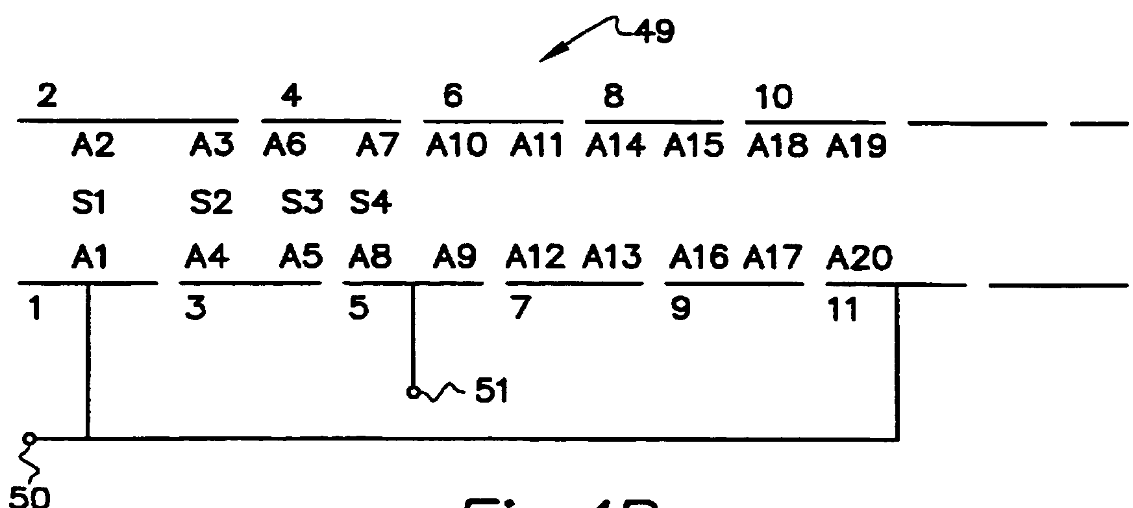


Fig. 4B

Fig. 5A

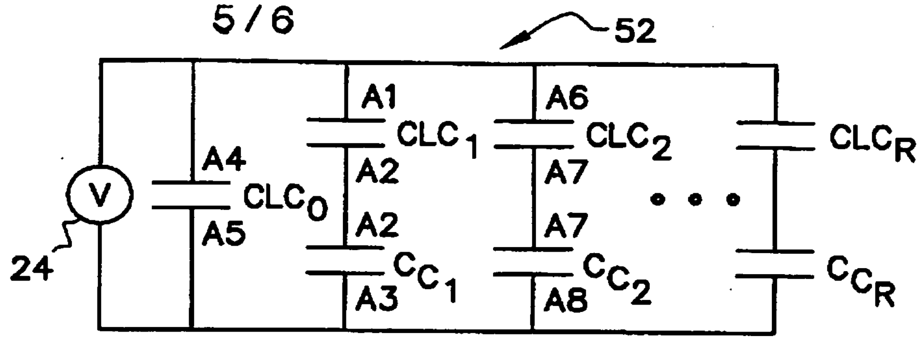
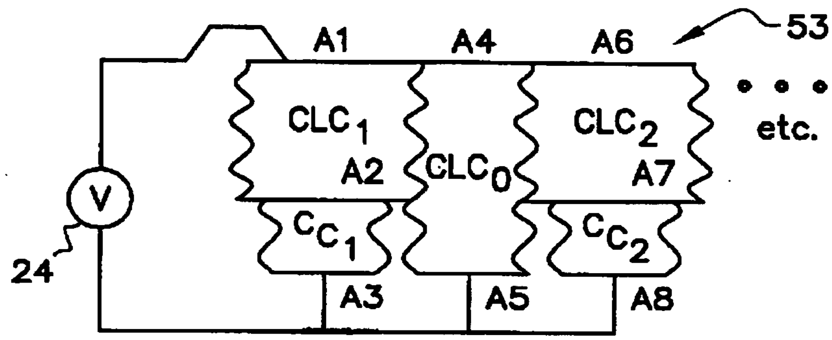


Fig. 5B



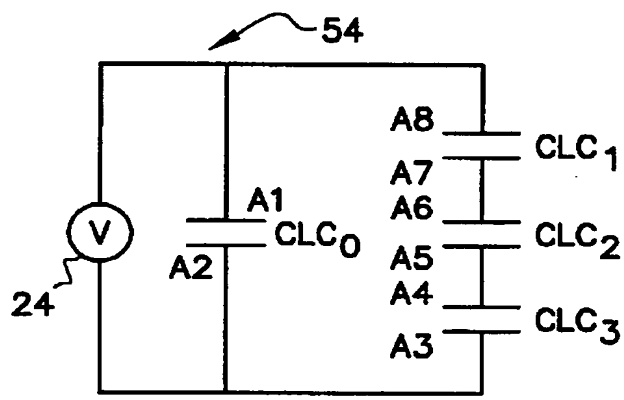


Fig. 5C

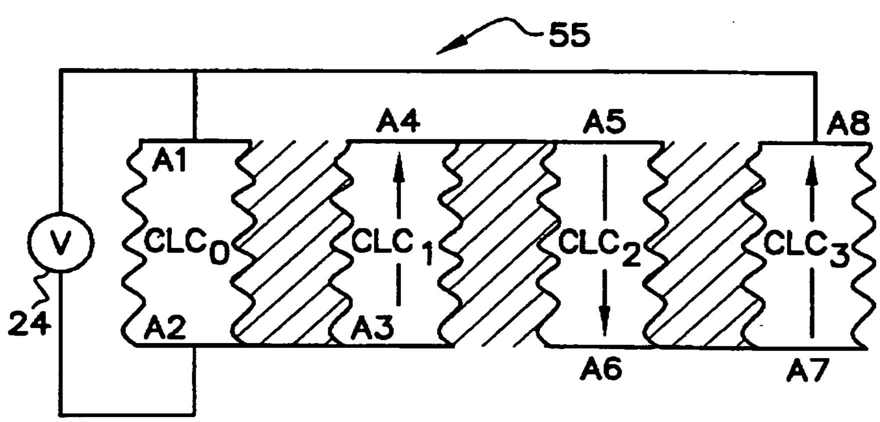
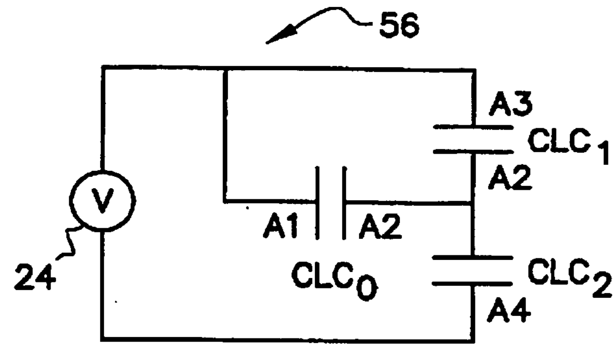


Fig. 5D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V
A1
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CLC0
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A4
24

Fig. 5E

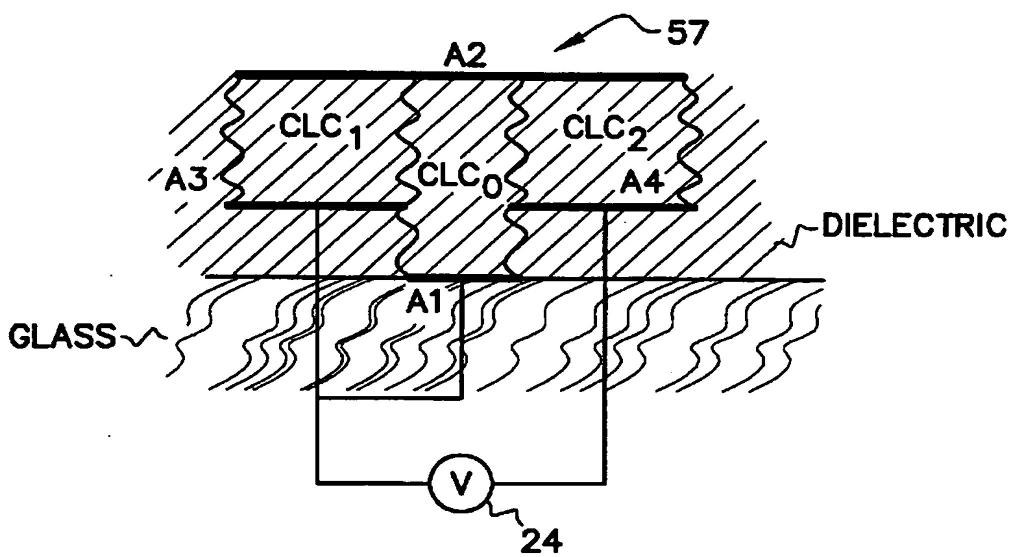
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Fig. 5F

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 94/01857

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G02F1/1343 G02F1/136

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP,A,0 030 387 (SIEMENS) 17 June 1981 see the whole document	1-21 22
X	WO,A,88 00717 (RAYCHEM) 28 January 1988 see page 4, line 26 - page 7, line 9 see page 10, line 29 - page 11, line 19; figures 1,2,6	1-21
Y A	EP,A,0 493 798 (HONEYWELL) 8 July 1992 see column 2, line 18 - column 3, line 11; figures 1,2	22 1-21
A	EP,A,0 468 452 (HOSIDEN) 29 January 1992 see abstract; figures 1-16	1-22
A	EP,A,0 166 948 (ENERGY CONVERSION DEVICES) 8 January 1986 see page 9, line 4 - line 34; figure 3	1,7, 13-18,20

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
3 June 1994	15.07.94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Stang, I

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 94/01857

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